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How ETAS Can Leverage Completeness of Modern Seismic Networks Without Renouncing Historical Data

Leila Mizrahi, Shyam Nandan, and Stefan Wiemer
ETH Zurich, Swiss Seismological Service, Depratment of Earth Sciences, Switzerland (leila.mizrahi@sed.ethz.ch)

The Epidemic-Type Aftershock Sequence (ETAS) model is often used to describe the spatio-temporal distribution of earthquakes. A fundamental requirement for parameter estimation of the ETAS model is the completeness of the catalog above a magnitude threshold m_c. m_c is known to vary with time for reasons such as gradual improvement of the seismic network, short term aftershock incompleteness and so on. For simplicity, nearly all applications of the ETAS model assume a global magnitude of completeness for the entirety of the training period. However, in order to be complete for the entire training period, the modeller is often forced to use very conservative estimates of m_c, as a result completely ignoring abundant and high-quality data from the recent periods, which falls below the assumed m_c. Alternatively, to benefit from the abundance of smaller magnitude earthquakes from the recent period in model training, the duration of the training period is often restricted. However, parameters estimated in this way may be dominated by one or two sequences and may not represent long term behavior.

We developed an alternative formulation of ETAS parameter inversion using expectation maximization, which accounts for a temporally variable magnitude of completeness. To test the adequacy of such a technique, we evaluate its forecasting power on an ETAS-simulated synthetic catalog, compared to the constant completeness magnitude ETAS base model. The synthetic dataset is designed to mimic the conditions in California, where m_c since 1970 is estimated to be around 3.5, and where a general decreasing trend in the temporal evolution of m_c can be observed. Both models are trained on the primary catalog with identical time horizon. While the reference model is solely based on information about earthquakes of magnitude 3.5 and above, our alternative represents completeness magnitude as a monotonically decreasing step-function, starting at 3.5 and assuming values down to 2.1 in more recent times.

To compare the two models, we issue forecasts by repeated probabilistic simulation of earthquake interaction scenarios, and evaluate those forecasts by assessing the likelihood of the actual occurrences under each of the alternatives. As a measure to quantify the difference in performance between the two models, we calculate the mean information gain due to model extension for different spatial resolutions, different temporal forecasting horizons, and different target magnitude ranges.

Preliminary results suggest that the parameter bias introduced by successive application of simulation and inversion decreases exponentially with an increasing fraction of data used in the

inversion. It is therefore expected that also the forecasting power of such a model increases with the amount of data available, indicating substantial importance of the method for the future of probabilistic seismic hazard assessment.